REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 02	Final Report (Nov 99 - Sep 01)

4. TITLE AND SUBTITLE
The Relationship between Facial Skin Surface Temperature Reactivity and Traditional Polygraph Measures Used in the Psychophysiological Detection of Deception: A Preliminary Investigation

5. FUNDING NUMBERS
DoDPI00-P-0011

6. AUTHOR(S)
Dean A. Pollina, Ph.D. and Andrew H. Ryan, Jr., Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
DoD Polygraph Institute
7540 Pickens Avenue
Fort Jackson, SC 29207

8. PERFORMING ORGANIZATION REPORT NUMBER
DoDPI02-R-0007

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
DoD Polygraph Institute
7540 Pickens Avenue
Fort Jackson, SC 29207

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
DoDPI00-P-0011/DoDPI02-R-0007

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Public Release

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This study investigated the feasibility of combining traditional polygraph measures including blood volume, respiration, and electrodermal activity with facial skin surface temperature (SST) changes recorded using high definition thermal imaging. Participants were randomly assigned to nondeceptive (n = 13) or deceptive (n = 12) treatment groups using a mock-crime scenario. The frequencies of accurate determinations made using traditional polygraph measures, SST measures, and a combination of polygraph and SST measures were compared using binary logistic regression. Highest accuracy was obtained using a combination of polygraph and SST measures, suggesting that recordings of facial SST provide information that may be useful when combined with traditional measures during a polygraph examination. These results are discussed in relation to orienting response (OR) theory.

Keywords: infrared thermography; polygraph; skin surface temperature; ZCT

14. SUBJECT TERMS

15. NUMBER OF PAGES
27

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U	U	U	U

Report No. DoDPI02-R-0007

DoD Polygraph Institute Research Division

The Relationship between Facial Skin Surface Temperature Reactivity and Traditional Polygraph Measures Used in the Psychophysiological Detection of Deception: A Preliminary Investigation

Dean A. Pollina, Ph.D. and Andrew H. Ryan, Ph.D.

Expect Success

Andrew H. Ryan, Jr.
Research Division Chief
(803) 751-5867
ryana@jackson-dpi.army.mil

Executive Summary

Data from several pilot studies suggest that thermal imaging technology might be a useful supplement to traditional polygraph measures used in the psychophysiological detection of deception. The purpose of this study was to assess the feasibility of combining traditional polygraph measures including blood volume, respiration, and electrodermal activity with facial skin surface temperature changes recorded using high definition thermal imaging.

Participants in this study were randomly assigned to nondeceptive or deceptive treatment groups. Participants in the deceptive group completed a mock-crime involving a simulated murder. A thermal imaging radiometer was used to monitor skin surface temperature while a specific-issue polygraph test was conducted. Traditional polygraph measures including electrodermal, cardiovascular, and respiratory activity were simultaneously recorded.

The highest deceptive/nondeceptive classification accuracy was obtained using a combination of polygraph and SST measures, suggesting that recordings of facial skin surface temperature provide information that may be useful when combined with traditional measures during a polygraph examination.

Acknowledgments

The authors would like to thank Kay Williams and Rose Swinford of the DoDPI Research Staff for their assistance with data collection procedures. We would also like to thank Gordon Barland and Don Krapohl, both of whom administered the polygraph exams to our study participants. We are also grateful to Johnnie Rodgerson for his advice concerning instructions given to deceptive participants, and Peter Reutiman for his technical assistance. This project was funded by the Department of Defense Polygraph Institute as project number DoDPI00-P-0011. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

Abstract

POLLINA, D. A. AND RYAN, A. H., JR. The Relationship between Facial Skin Surface Temperature Reactivity and Traditional Polygraph Measures Used in the Psychophysiological Detection of Deception: A Preliminary Investigation. April 29, 2003, DoDPI02-R-0007, Department of Defense Polygraph Institute, Fort Jackson, SC 29207. This study investigated the feasibility of combining traditional polygraph measures including blood volume, respiration, and electrodermal activity with facial skin surface temperature (SST) changes recorded using high definition thermal imaging. Participants were randomly assigned to nondeceptive ($n = 13$) or deceptive ($n = 12$) treatment groups using a mock-crime scenario. The frequencies of accurate determinations made using traditional polygraph measures, SST measures, and a combination of polygraph and SST measures were compared using binary logistic regression. Highest accuracy was obtained using a combination of polygraph and SST measures, suggesting that recordings of facial SST provide information that may be useful when combined with traditional measures during a polygraph examination. These results are discussed in relation to orienting response (OR) theory.

Keywords: infrared thermography; polygraph; skin surface temperature; ZCT

Table of Contents

Recent research suggests that many emotions are accompanied by specific physiological, biochemical, and behavioral responses (Ekman, Hager, & Friesen, 1981). According to Ekman, (1992) facial expressions are the richest source of information about the underlying emotional states that accompany them. There is evidence that the involuntary facial expressions of emotion are the product of evolution, and many human facial expressions are seen on the faces of other primates. Additionally, researchers have met with some success using the patterns of facial muscle activity that are ultimately responsible for the expression of an emotion to discover additional information about emotions in humans. The muscles involved in facial expression have been used in an attempt to determine which specific emotion is felt, the strength of the felt emotion, and whether more than one emotion is being experienced at a given time (Ekman, 1992; Ekman, Freiesen, & Ancoli, 1980; Sackeim, Gur, & Saucy, 1978). Importantly, this research shows that certain facial expressions of emotions are not under voluntary control and can occur even when research participants do not want them to.

The findings that certain facial expressions are involuntary and products of evolution have led several researchers to investigate the possibility that these facial expressions might betray the deceptive utterances of lairs. If so, behavioral studies of changes in facial expression might be a useful addition to the battery of psychophysiological detection of deception (PDD) measures employed by polygraph examiners (who typically monitor cardiovascular, electrodermal, and respiratory activity) as a series of questions that relate to an incident under investigation are being asked. Unfortunately, this line of research is made more difficult to interpret because involuntary facial expressions are very quickly masked. In the end, the muscles of the face are largely under voluntary control. Several studies with chimpanzees (Woodruff & Premack, 1979)

and humans (Ekman & O'sullivan, 1991) show that research participants can suppress some of the behaviors that convey accurate information when they are attempting to deceive someone. One technology that shows promise in overcoming some of the limitations of behavioral studies of facial expression is thermography. Thermography is a technique used for measuring radiant energy or natural heat (infrared) emission from the human body (Gorbach, 1993). Using infrared (IR) radiometry, heat measurements from large areas of the body surface can be made without skin contact. Skin surface temperature (SST) is affected by changes in underlying muscle activity and microcirculation. Increases in muscle activity result in increases in blood flow to the arterioles surrounding the muscle, and these changes are associated with a rise in heat production (Grayson, 1990).

In addition to the SST changes caused by facial muscle activity, sympathetic vasodilatation and constriction are involved in facial flushing in response to body heating and embarrassment (Drummond & Lance, 1987). Fox et al., (1962) showed that vasomotor control of certain areas of the face involves variations in vasoconstriction, whereas vasomotor control of other facial areas involves vasodilatation. Both mechanisms appear to play a part in regulating the circulation of blood in the skin overlying the nose. Cervical sympathetic fibers are most likely involved in producing this vasodilatation and vasoconstriction. The distribution of heat radiating from the face is also affected by facial sweating, which, like flushing, is controlled by the sympathetic branch of the ANS. Given all the factors that can contribute to changes in facial SST, it is likely that the patterns of SST responses to questions during a polygraph examination are extremely complex. By combining the traditional ANS measures used in the psychophysiological detection of deception with rapid-response facial SST measures, it was predicted that a more complete picture of the psychophysiological processes that accompany deliberate deception would emerge. Of particular interest was the hypothesis that specific facial

areas would be differentially affected by participants' fear-induced central and ANS responses to specific test questions. It was also hoped that the SST information would contribute to more effective discrimination of deceptive and nondeceptive individuals than the traditional polygraph measures alone.

Method

Participants

Thirty participants (20% Female) between the ages of 19 and 28 (M = 21.2) were recruited from a sample of U.S. Army basic trainees stationed at Fort Jackson, South Carolina and assigned to duty at the Department of Defense Polygraph Institute (DoDPI). All participants were given the option of participating in this research study, or watching television or reading in the DoDPI library for the day. Only interested volunteers were selected for participation. All participants were in good health by self-report, and no one was taking any medications except for pain killers (e.g. ibuprofen) because of minor injuries sustained during basic training. Five participants were dropped from the study due to incriminating statements made to the polygraph examiner (n = 1), sleeping during the polygraph examination (n = 2), or failure or unwillingness to commit the mock crime (n = 2). This resulted in the inclusion of 25 participants (12 deceptive, 13 nondeceptive) in the final data analyses[1].

Apparatus

Polygraph recordings were obtained using Axciton model field polygraphs (Axciton Systems, Inc, Houston TX). All examinations included measures of respiration, relative blood volume, and electrodermal activity. A Raytheon model FPA thermal imaging radiometer was used to monitor SST. The radiometer 12-bit digital output was connected to a high-speed digital video processing board supplied with software designed specifically for thermal imaging installed in a Pentium III 466 Mhz computer. A mock-crime room including a plastic dummy,

purse, screwdriver, and chair was also used. Physiological data were collected in a darkened, temperature controlled room (Range: 20-22^0 C).

General Procedure

All interested participants were instructed to read a brief description of this research project and sign an informed consent form. Each participant then answered a series of biographical and medical questions to ensure that they were in good health and not taking medication that could potentially interfere with the examination results. After all forms were completed, the investigator explained how the polygraph examination would be conducted. Each participant was randomly assigned to either the deceptive or non-deceptive group. Participants in the nondeceptive group were told that they would be taking a polygraph test as part of a research study and questioned about the murder of a woman that took place at the DoDPI earlier that day. Since they did not commit this crime, they were instructed to answer all questions truthfully during the polygraph examination. Participants assigned to the deceptive group were told that they would be involved in a pretend crime, and would lie about this during the polygraph examination in an attempt to appear innocent. Participants then either waited quietly to be brought to the polygraph examination room (non-deceptive group) or committed a pretend crime (deceptive group).

Procedure for Deceptive Group

Prior to each participant's arrival at the DoDPI, a mock crime room was constructed. In the room, a plastic dummy was seated in a chair. A purse containing $20 USD was placed next to the dummy, and a screwdriver was placed on a table next to the purse. Participants in the deceptive group were instructed by the investigator to enter the mock-crime room without being seen, stab the dummy with the screwdriver, and steal the $20 from the purse. After committing the mock crime, each participant was asked details about the crime by the experimenter.

Questions included, “Were you seen by anyone? Did you remember to steal the $20? What happened to the woman in the room?” Participants who failed to stab the dummy and steal the $20 were excluded from this study.

Data Collection Procedures

At a prearranged time, each participant was met by a U.S. Government certified polygraph examiner, who was blind to the participant’s group membership. Sensors were attached to the participant in the following locations: electrodermal finger plates on the distal-medial phalanges of the first and third fingers of the (typically) nondominant hand, blood presssure cuff on the (typically) dominant arm above the brachial artery, and pneumographic chest assemblies across the pectoralis major muscles (“upper” pneumograph) sensor under the arm and across the rectus abdominis immediately above the navel (“lower” pneumograph) sensor. Each participant was questioned briefly about the crime, and then the polygraph test questions, in a Zone Comparison Test format (DoDPI, 1994) were reviewed. The questions asked during data collection included crime relevant questions, comparison questions, and crime-irrelevant questions (Table 1). Ten questions were presented during a single series, and each series was repeated three times during the polygraph examination. Each question was presented approximately 25 seconds after the onset of the previous question.

Data Reduction: Polygraph Measures. The upper and lower pneumograph, electrodermal, and cardiovascular responses to each question were sampled at a rate of 15 samples/s and interpolated to a rate of 60 samples/s for all subsequent analyses. Digitized (ASCII) data collected from each of the four polygraph channels during each repetition of a question sequence were standardized using z-score transformations. The standardized data were then separated by Question Type (R5, R7, R10, C4, C6, C9) using the onset of each of the examiner’s questions as

the beginning of the analysis interval and the onset of the examiner's next question as the end of the analysis interval. Dependent measures included maximum amplitude of the blood volume and electrodermal responses, and Euclidean distance between successive timepoints ("line length") in the upper and lower pneumograph responses (Kircher, 1983; 1984; Kircher & Raskin, 1988). Blood volume, electrodermal, and line length responses were calculated for each of the

Table 1.

Questions Asked by the Polygraph Examiner

Test Question	Question Type
Is your Name ________?	Not Scored
Regarding whether you stabbed that woman today, do you intend to answer my questions about that truthfully?	Not Scored
Do you understand that I will not ask any trick or surprise questions on this test?	Not Scored
Before arriving at Fort Jackson, did you ever seriously hurt someone who trusted you?	C1
Did you stab that woman today?	R1
Before arriving at Fort Jackson, Did you ever lose your temper when you shouldn't have?	C2
Did you stab that woman in that room today?	R2
Is there anything you are afraid I will ask you a question about even though I said I wouldn't?	Not Scored
Before this year, did you ever take anything important that didn't belong to you?	C3
Do you have that stolen $20 on you right now?	R3

three relevant (R1, R2, R3) and comparison (C1, C2, C3) questions asked during each of the three question series presented during the polygraph examination.

To determine maximum amplitude of the blood volume response, difference scores in relative units were obtained between each low point and successive high points identified in each response curve using a 13.7 s analysis window. Maximum amplitude of the blood volume response was defined as the greatest such difference. Maximum amplitude of the electrodermal response was determined in a similar manner with a 5 s analysis window for determination of minimum amplitude. Length of the upper and lower pneumograph tracing was determined by measuring the Euclidean distance between successive pairs of samples obtained every 1/60 s for 10 poststimulus seconds. The resulting 600 measurements were summed to yield a length measure in relative units for each respiration channel. Difference scores were obtained for blood volume response measures by subtracting, for each subject, mean responses to each comparison question from mean responses to each adjacent relevant question. Similar subtraction measures were also derived for electrodermal, and upper and lower pneumograph responses. By collapsing across question type and question sequence yielded a single (comparison question – relevant question) subtraction measure for each participant.

Data Reduction: SST Measures. Recordings of facial temperature values were started at the onset of each of the examiner's relevant (R1, R2, R3) and comparison (C1, C2, C3) questions using a 30 Hz sampling rate for ten seconds (300 image frames) and a 256 x 256 FPA. Thermal image data collection was started with the press of a computer key after a prearranged signal (finger tap) from the polygraph examiner prior to beginning each question in the sequence. The resulting (256 x 256 x 300) array of temperature values collected during the presentation of each question was converted to an ASCII text file and stored on a CD-RW disc for off-line data analysis. Three "subtraction" temperature arrays were created for each question sequence by

subtracting each point in the relevant question temperature array from the corresponding point in the adjacent comparison question temperature array. Due to data storage limitations, SST data were not collected during the third repetition of the question sequence. This resulted in a total of six subtraction temperature arrays generated for each participant.

To test the hypothesis that comparison question – relevant question temperature differences across the face are related to deception, temperature/timepoint waveforms from fourteen facial areas were selected for analysis. All fourteen of the selected facial areas overlie muscles involved in facial expression (Martini, 1998). To determine maximum amplitude of the SST responses at each facial area, difference scores in relative units were obtained between the lowest and highest point on each waveform using the 10 s analysis window in each subtraction array (Figure 1). For those facial areas that were bilaterally symmetric (e.g., mouth, ears, neck, eyes, scalp), SST maximum amplitudes were collected on both the left and the right side of the face. The average of each pair of measures was used in all subsequent statistical analysis. Finally, average waveforms were created by collapsing across facial areas overlying muscles

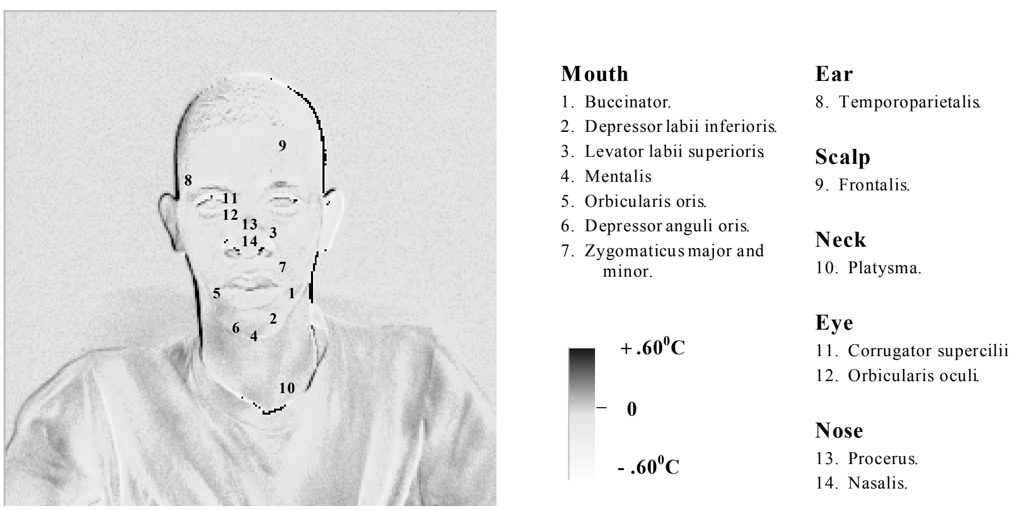


Figure 1. First frame in (comparison question – relevant question) subtraction SST array which began at the onset of a single question spoken by the polygraph examiner. Numbers indicate sites chosen for thermal image analysis. All sites were skin surface areas overlying muscles involved in facial expression.

controlling the mouth (Areas 1- 7), ear (Area 8), scalp (Area 9), neck (Area 10), eye (Areas 11 and 12), and nose (Areas 13 and 14).

Results

Facial SST Maximum Amplitudes. Figure 2 shows grand average waveforms, collapsing across individual participants' responses, at each of six facial areas. Reliable SST waveforms were generated to all comparison and crime-relevant questions asked during the first two repetitions of the ZCT test. Visual inspection of the grand average waveforms suggests that skin surface regions in areas around the nose and eyes manifested the largest amplitude group differences. It also appears that SST response latencies differed at each facial region. Specifically, peak latencies appear as a traveling wave, with shortest peak latencies at the ear, scalp and nose. Peak latencies are longer in the mouth and neck regions, and the periorbital eye regions showed the longest peak latencies in the grand average waveforms (Figure 2). A between-groups multivariate analysis of variance was performed on the six dependent variables associated with the thermal imaging measures. The combined thermal imaging DVs were not

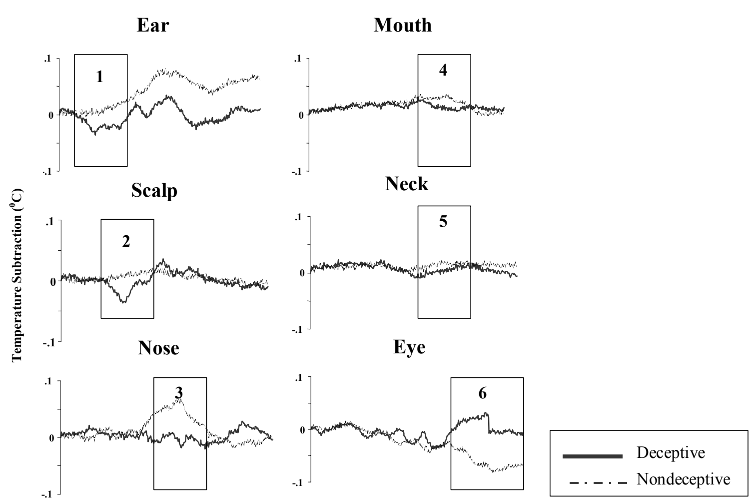


Figure 2. Grand Average SST waveforms, collapsing across individual participants' responses, at each of six facial skin surface areas, including mouth, ear, neck, nose, eye, and scalp. Temperature changes appear as a traveling wave from time intervals 1 – 6. S

significantly related to (Deceptive/ Nondeceptive) group membership $F(6, 17) = .29$, n. s, $\eta^2 = .09$.

Polygraph Measures. Maximum amplitude of the blood volume and electrodermal responses, as well as respiration line length all showed the predicted response patterns. Specifically, maximum amplitudes of the blood volume and electrodermal responses were larger to the relevant questions in deceptive participants, and larger to the comparison questions in nondeceptive participants (Table 2). Respiration line length showed the (predicted) opposite pattern. Respiration line lengths decreased to a greater degree in response to the relevant questions in deceptive participants, and decreased to a greater degree in response to the comparison questions in nondeceptive participants. A between-groups multivariate analysis of variance was performed on the four dependent variables associated with the traditional polygraph measures. With the use of Wilks' criterion, the combined polygraph DVs were significantly related to (Deceptive/ Nondeceptive) group membership $F(1, 22) = 5.61$, $p < .01$, $\eta^2 = .54$.

SST/Polygraph Classification Accuracy. The ability to classify individuals into deceptive and nondeceptive groups based on blood volume, electrodermal, and pneumograph measures was examined using binary logistic regression. Maximum amplitude of the blood volume response, maximum amplitude of the electrodermal response, and (upper and lower) pneumograph Euclidean distance (relevant question – comparison question) subtraction measures were entered into the logistic regression equation as each of four covariates in a single block. As predicted, these four variables accounted for a significant proportion ($R^2 = .41$) of the variation in the regression model, X^2 (4, $N = 24$) = 12.6, $p < .01$. Next, maximum amplitude of the skin temperature responses from the nose, mouth, neck, eye, scalp, and ear (relevant question – comparison question) subtraction measures were entered as each of six covariates in a separate logistic regression analysis. These six SST variables were entered in a single block. These

variables failed to account for a significant proportion ($R^2 = .09$) of the variation in the model, X^2 (6, $N = 24$) = 2.3, n. s.

Table 2.

Mean (+/- S. E. M.) SST and Polygraph Subtraction Measures

Comparison – Relevant Subtraction Measure	Deceptive Participants	Nondeceptive Participants
Maximum SST Amplitude*		
Mouth	20.96 (+/- 1.68)	18.99 (+/- 1.52)
Ear	23.66 (+/- 4.87)	21.86 (+/- 2.87)
Scalp	17.00 (+/- 3.94)	14.08 (+/- 1.47)
Neck	12.64 (+/- 1.62)	11.02 (+/- 1.03)
Eye	39.64 (+/- 5.44)	43.42 (+/- 7.60)
Nose	22.35 (+/- 3.79)	24.05 (+/- 4.74)
Polygraph Measures		
Maximum EDA Amplitude	-.83 (+/- .15)	.07 (+/- .23)
Maximum BV Amplitude	-.90 (+/- .35)	-.66 (+/- .36)
Respiration Line Length (Upper)	.37 (+/- .30)	.04 (+/- .26)
Respiration Line Length (Lower)	.49 (+/- .34)	.05 (+/- .32)

Note. The units of measure for thermal data are digital values recorded from the camera. An increase of one digital unit is ≈ .013 degree Celsius.

To determine whether an interaction between traditional polygraph measures and SST amplitudes could result in better predictive value than using either approach alone, the four polygraph measures (upper and lower pneumograph line length, blood volume and electrodermal maximum amplitude) were combined with nose SST maximum amplitude in a two-step binary logistic regression analysis. Using these five measures as covariates, the logistic regression

equation again accounted for a significant proportion ($R^2 = .49$) of the variation in the regression model, $X^2(5, N = 24) = 16.0$, $p < .01$. This logistic regression equation also reached significance when the eye SST maximum amplitude measure was substituted for nose SST at step 2, $X^2(5, N = 24) = 14.6$, $p < .01$, and again when nose SST and eye SST were both entered at step 2, $X^2(6, N = 24) = 17.5$, $p < .01$. However, the increase in the proportion of variance accounted for by the SST variables entered at step 2 failed to reach statistical significance, $X^2(2, N = 24) = 2.8$, n.s.

Next, the *c* statistic, equal to the area under the ROC curve, was calculated for each of the logistic regression analyses previously performed (See Hanley and McNeil, 1982 for an explanation of the *c* statistic). Case inclusion cutoff probability was set at .5, with probabilities < .5 classified as deceptive and probabilities > .5 classified as nondeceptive. Results show a shift in the probability distribution toward correct classification when both traditional polygraph measures and SST measures are combined (Table 3). Logistic regression analysis generates a direct estimate of the probability of an event occurring. This feature allows for an arbitrary case inclusion cutoff probability, which was included in the above analysis to generate an "inconclusive" column. Typically, a certain number of field polygraph examiners' test results are inconclusive. Table 4 shows the number of correct, incorrect, and inconclusive (no opinion) results at .50, .60, .70, .80 and .90 cutoff probability levels. Results indicate that the combination of Polygraph measures combined with SST from the eye and nose facial regions yields the most robust discrimination of group membership, especially at the more stringent criteria.

Table 3.

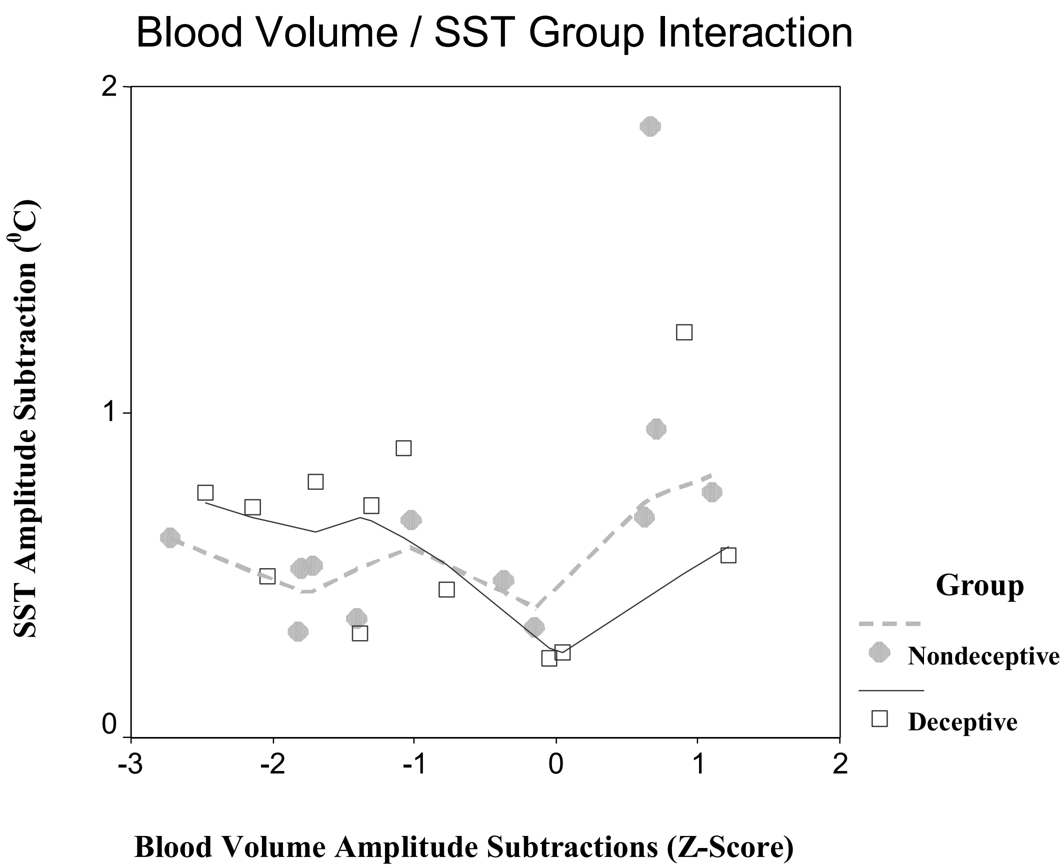
Area Under the ROC Curve Derived from Binary Logistic Regression

Regression Analysis	Predictor Variables	R^2 (Cox & Snell)	ROC Area	Sig. *
Polygraph Measures	BV, EDA, AR, TR	.41	.88	.002
SST Amplitude Measures	SST: Nose, Mouth, Eye, Scalp, Neck, Ear	.09	.70	.09 (N.S.)
Polygraph and SST Amplitude: Nose	BV, EDA, AR, TR, SST: Nose	.49	.90	.001
Polygraph and SST Amplitude: Eye	BV, EDA, AR, TR, Eye	.46	.90	.001
Polygraph and SST Amplitude: Eye, Nose	BV, EDA, AR, TR, SST: Eye, Nose	.52	.92	.001

*Null hypothesis: true area = .50

The increases in classification accuracy achieved with the combination of polygraph and SST measures suggest that a degree of orthogonality exists among the polygraph and SST measures. To examine this, bivariate (Pearson) correlations were performed between a composite SST measure (collapsing across eye and nose) and cardiovascular, electrodermal, and respiration polygraph measures. Using the entire sample, none of these correlations reached significance at the .05 level. However, an additional analysis conducted on the subgroups of deceptive and nondeceptive individuals showed an interaction between maximum amplitude of the cardiovascular response to crime-relevant questions and composite SST maximum amplitudes to relevant questions. Deceptive individuals whose cardiovascular responses were

least responsive to the crime relevant questions had the most responsive SST responses to crime-relevant questions. Nondeceptive individuals with largest cardiovascular responses to the crime-relevant questions also had the most responsive SST responses to the relevant questions (Figure 3).



<u>Figure 3</u>. Scatterplot showing the relationship between blood volume measures derived from sphygmomanometer recording over brachial artery and skin surface temperature recordings from the eye and nose regions of the face. Fit-lines through each group's data were calculated using a lowess model with 50% points-to-fit.

Table 4.

Classification Table: Binary Logistic Regression

Cutoff Score	Polygraph Measures			Polygraph & SST: Eye			Polygraph & SST: Nose			Polygraph & SST: Eye, Nose		
	Hit	Miss	Inc.	Hit	Miss	Inc.	Hit	Miss	Inc.	Hit	Miss	Inc.
.5/.5	16	8	0	19	5	0	21	3	0	20	4	0
.6/.4	16	4	4	17	2	5	16	3	5	18	3	3
.7/.3	15	2	7	15	2	7	14	1	9	16	2	6
.8/.2	14	0	10	12	2	10	12	1	11	15	0	9
.9/.1	7	0	17	11	0	13	12	0	12	12	0	12

To test whether the effect shown in Figure 3 was statistically significant, raw values from each participant's SST and Cardiovascular subtraction measures were re-coded into a single dichotomous variable. Participants with negative CQ – RQ subtraction scores and low CQ – RQ SST (eye and nose) received a value of +1. Participants with positive CQ – RQ subtraction scores and high CQ – RQ SST (eye and nose) received a value of +1. Participants with negative CQ – RQ subtraction scores and high CQ – RQ SST (eye and nose) received a value of -1. Participants with positive CQ – RQ subtraction scores and low CQ – RQ SST (eye and nose) received a value of -1. A Spearman correlation (phi-coefficient) between these re-coded values and (Deceptive/ Nondeceptive) group membership was significant ($r = .43$, $p < .05$). This result is shown in Table 5.

Table 5.

Combined Blood Volume and SST Measures For each Group

Re-coded Variable	*Group Assignment*			
	Deceptive		Nondeceptive	
	Count	%	Count	%
-1	7	58.3	2	16.7
+1	5	48.7	10	83.3

Note. High CQ – RQ SST and High CQ – RQ BV = +1; Low CQ – RQ SST and Low CQ – RQ BV = +1; High CQ – RQ SST and Low CQ – RQ BV = -1; Low CQ – RQ SST and High CQ – RQ BV = -1

Discussion

The results of this study suggest that thermal image analysis, when combined with traditional polygraph measures, can be effective in discriminating deceptive and nondeceptive individuals during a polygraph test. Using high-definition, rapid response thermal imaging, real-time changes in skin surface temperature across the face were effectively recorded. Skin surface temperatures overlying muscles around the eyes and nose appeared to be the most effective predictors of deception, but only when combined with the traditional polygraph measures of respiration, cardiovascular, and electrodermal activity. The finding that dichotomous classifications based on a combination of SST and BV amplitudes significantly correlated with group membership also suggests that a combination of SST and traditional polygraph measures might lead to more effective means of detecting deception. These findings also give some support to the theory that unique facial heat signatures and perhaps neuromuscular patterns are associated with specific emotions (Ekman, Hagar, & Friesen, 1981; Ekman, Levenson, and Friesen, 1983; Pavlidis, Eberhardt, & Levine, 2002). However, more work will be necessary to

effectively determine the relationship between cardiovascular and neuro-muscular activity, SST, and emotional states.

Using measures of vagal tone derived from the electrocardiogram, Raskin and Kircher (1990) found that deceptive participants showed less vagal response to relevant questions than to comparison questions. Nondeceptive participants showed the opposite pattern. Vagal tone is a measure of parasympathetic (vagus nerve) influence on heart rate (Porges et al., 1980). However, a subsequent study failed to find any significant correlation between vagal tone measures and ground truth using a mock crime scenario (Kircher, Packard, Bell, & Bernhardt, 2001). These discrepant findings suggest that the contribution made by the parasympathetic branch of the ANS to the psychophysiological detection of deception is modest when standard cardiovascular measures are used. However, measures such as SST, which can be taken from many regions of the body simultaneously, could be effective in revealing the differential effects of the sympathetic and parasympathetic branches of the ANS on microcirculation in capillaries near the skin's surface. One possibility is that the SST/BV interactions seen in the present study are the result of combined sympathetic and parasympathetic effects on SST. Future studies investigating the separate component processes that underlie facial SST during a PDD examination could be useful in answering this question.

Several fundamental emotions have been shown to exist across different cultures, and attempts have been made to link these emotions to specific facial expressions (Ekman, Friesen, & Ellsworth, 1972; Izard, 1972). The face has a high ratio of motor units to muscle mass and extensive neural innervation, and facial EMG patterning has been shown to be sensitive to different emotional states elicited by affective imagery (Schwartz, Fair, Salt, Mandel, & Klerman, 1976). These patterns are not typically noticeable in the overt face (Schwartz, 1986). The results of the present study suggest that SST patterns might also be sensitive to specific

emotions, but the exact nature of the resulting temperature patterns is not yet known. Sites chosen for SST analysis in the present study were those that overlie muscles involved in facial expression. However, it is still unclear whether the observed temperature changes are highly correlated with activity in specific muscle groups. The two sites most predictive of deception in the present study were the periorbital regions around the eyes and the nose.

Although there is no unified theory that explains the effectiveness of the PDD process, most parsimonious explanations involve orienting and defensive responses (Sokolov, 1963, Sokolov & Cacioppo, 1997). Changes in blood volume are part of the orienting response (OR) first described by Sokolov, (1963), who reported decreases in forehead blood volume in response to threatening stimuli. According to OR the theory proposed by Sokolov, these decreases in cephalic blood volume reflect a defensive response (DR) that protects the organism from harm. Conversely, novel or unexpected stimuli produce increases in forehead blood volume which reflect an orienting response that improves perceptual ability. More recent studies investigating orienting and defensive responses have shown that individual differences play a role in cardiac responses to fear stimuli. In one study, subgroups of individuals showed acceleratory, deceleratory, and moderate deceleratory responses to pictures of homicide victims (Hare, 1972). These results have been interpreted to suggest that a given stimulus can evoke DRs in some participants, and ORs in other participants (Cook & Turpin, 1997). The results of the present study also suggest that, in the forehead and periorbital region, the situation is complex. A multivariate approach to the study of facial SST, based on the principle of a multidimensional space including sympathetic-parasympathetic inputs to the heart and face may be useful in determining the components of the observed facial temperature distribution in response to threatening stimuli.

References

Cook, E. and Turpin, G. (1997). Differentiating orienting, startle, and defense responses: The role of affect and its implications for psychopathology. In: P. Lang, R. Simons, & M. Balaban, (Eds.), *Attention and Orienting: Sensory and Motivational Processes*. New Jersey: Lawrence Erlbaum Associates.

Department of Defense Polygraph Institute. (1994). *ZCT, Zone Comparison Test*. Unpublished Manuscript, Department of Defense Polygraph Institute.

Drummond, P., and Lance, J. (1987). Facial flushing and sweating mediated by the sympathetic nervous system. *Brain*, *110*, 793-803.

Ekman, P. (1992). *Telling Lies: Clues to Deceit in the Marketplace, Politics, and Marriage*. New York: W. W. Norton & Company.

Ekman, P., Friesen, W., and Ancoli, S. (1980). Facial signs of emotional experience. *Journal of Personality and Social Psychology*, *39*, 1125-1134.

Ekman, P., Friesen, W., and Ellsworth, P. (1972). *Emotion in the Human Face*. Elmsford NY: Pergamon Press.

Ekman, P., Hager, J., and Friesen, W. (1981). The symmetry of emotional and deliberate facial actions, *Psychophysiology*, *18*, 101-106.

Ekman, P., Levenson, R. & Friesen, W. (1983). Autonomic nervous system activity distinguishes among emotions. *Science*, *22*, 1208-1210.

Ekman, P., and O'Sullivan, M. (1991). Who can catch a liar. *American Psychologist*, *46*, 913-920.

Fox, R., Goldsmith, R., and Kidd, D. (1962). Cutaneous vasomotor control in the human head, neck, and upper chest. *Journal of Physiology*, *161*, 298-312.

Grayson, J. (1990). Responses of the microciculation to hot and cold environments. In:

W.C. Bowman, E. Schönbaum, & P. Lomax (Eds.), *Thermoregulation: Physiology and Biochemistry* (pp. 221-234). New York: Pergamon Press.

Gorbach, A. M. (1993). Infrared imaging of brain function. In: U. Dirnagl, A. Villringer, & K.M. Einhaupl (Eds.), *Optical Imaging of Brain Function and Metabolism* (pp. 95-123). New York: Plenum Press.

Hanley, J. A., and McNeil, B. J. (1982). The meaning and use of the area under a receiver-operating characteristic (ROC) curve. *Radiology*, *143*: 29-36.

Hare, R. (1972). Cardiovascular components of orienting and defensive responses. *Psychophysiology*, *9*, 606-614.

Izard, C. (1972). *Patterns of Emotions*. New York: Academic Press.

Kircher, J. C. (1983). *Computerized decision-making and patterns of activation in the detection of deception*. Unpublished doctoral dissertation, University of Utah.

Kircher, J. C. (1984). Uses and abuses of the mock crime paradigm in research on field polygraph techniques. *Psychophysiology*, *21*, 566.

Kircher, J. C., & Raskin, D. C. (1988). Human versus computerized evaluations of polygraph data in a laboratory setting. *Journal of Applied Psychology*, *73*, 291-302.

Kircher, J. C., Packard, T., Bell, B. G., & Bernhardt, P.C. (2001). Effects of prior demonstrations of polygraph accuracy on outcomes of probable-lie and directed-lie polygraph tests (Grant No. DoDPI-02-R0002). *University of Utah*, Department of Educational Psychology.

Martini, F. H. (1998). *Fundamentals of Anatomy and Physiology* (4th Ed.). New Jersey: Prentice Hall, Inc.

Pavlidis, I., Eberhardt, N. L., & Levine, J., (2002). Human behavior: Seeing through the

face of deception. *Nature*, *415*, 35.

Porges, S., Bohrer, R., Cheung, M., Drasgow, F., McCabe, P., & Keren, g. (1980). New time series statistic for detecting rythmic co-occurrence in the frequency domain: The weighted coherence and its application to psychophysiological research. *Psychological Bulletin*, *88*, 580-587.

Raskin, D., & Kircher, J. (1990). Development of a computerized polygraph system and physiological measures for detection of deception and countermeasures: A pilot study (Contract 88-L55300-000). Salt Lake City: *Scientific Assessment Technologies*.

Sackeim, H., Gur, R., and Saucy, M. (1978). Emotions are expressed more intensely on the left side of the face, *Science*, *202*, 434.

Schwartz, G. (1986). Emotion and psychophysiological organization: A systems approach. In M. Coles, E. Donchin, & S. Porges, (Eds.) *Psychophysiology: Systems, Processes, and Applications*. New York: Guilford Press.

Schwartz, G. E., Fair, P. L., Salt, P., Mandel, M. R., & Klerman, G. L. (1976). Facial muscle patterning to affective imagery in depressed and nondepressed subjects. *Science*, *192*, 489-491.

Sokolov, E. (1963). *Perception and the conditioned reflex*. New York: Macmillan.

Sokolov, E. and Cacioppo, J. (1997). Orienting and defense reflexes: vector coding the cardiac response. In: P. Lang, R. Simons, & M. Balaban, (Eds.), *Attention and Orienting: Sensory and Motivational Processes*. New Jersey: Lawrence Erlbaum Associates.

Woodruff, G., and Premack, D. (1979). Intentional communication in the chimpanzee: The development of deception. *Cognition*, 7, 333-362.

Footnotes

[1]Data on examiner decisions (deceptive / nondeceptive) for a subset of the data reported here was published previously in the journal *Nature*. The *Nature* article also reported the first use of a classification algorithm utilizing thermal imaging data in the periorbital region. See references section for a complete citation.